Infiltration of Stormwater and Drinking Water Quality

May 2015

Brandon Kernen
New Hampshire Department of Environmental Services

NHDES and EPA – Stormwater Management Promote Groundwater Recharge

- Federal Clean Water Act
- State Alteration of Terrain Permits
- Green Infrastructure Initiatives

Quantity Impacts - Direct Discharge of Stormwater to Surface Water

- Changes to Stream Flow
- Increased runoff velocities
- Increased flooding
- Lower baseflows (dry weather flows)
- Less water is stored in aquifers

Stream Morphology Impacts - Direct Discharge of Stormwater to Surface Water

- Changes to Stream Geomorphology
- Stream degradation or aggradation, resulting from changes in flows or sediment load
- Loss of riparian vegetation & canopy

Ecological Impacts - Direct Discharge of Stormwater to Surface Water

- Changes to Aquatic Habitat
- Increased stream temperatures
- Decline in abundance and biodiversity of fish and benthic organisms

Quality Impacts - Direct Discharge of Stormwater to Surface Water

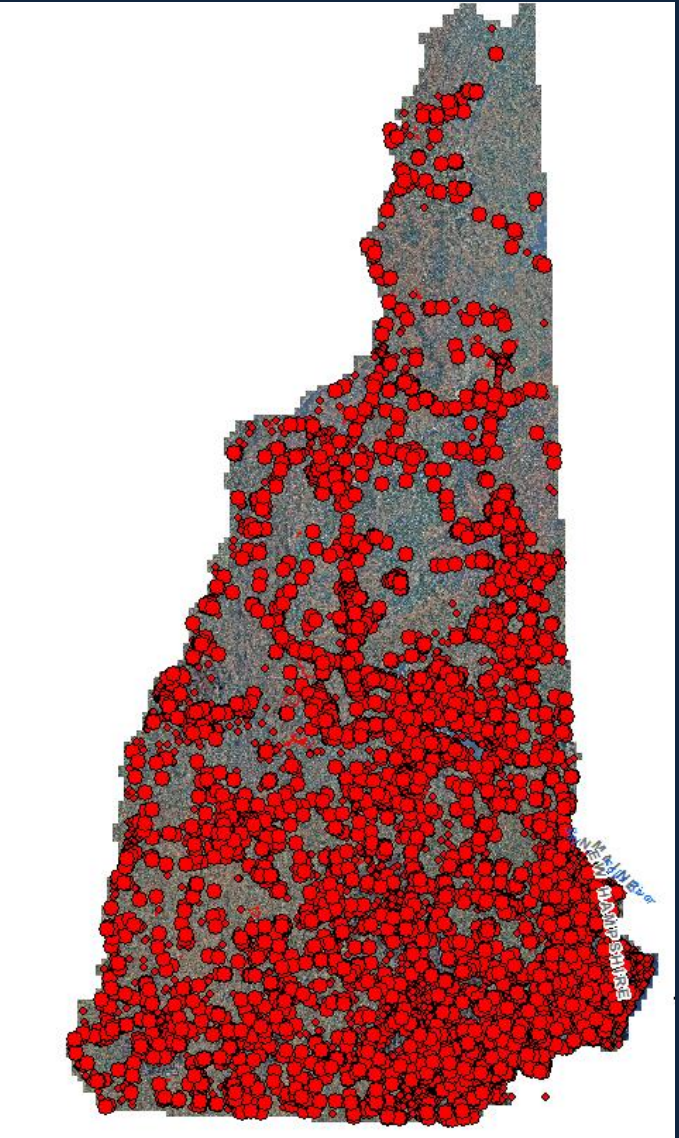
- Pathogenic bacteria/viruses
- Nuisance algal growth from excess nutrients in runoff.
- Contamination from nitrogen compounds, metals, organic compounds, pesticides & salts
- Depleted dissolved oxygen (DO) levels.
- Increased temperatures

Question

What is the impact of discharging stormwater to groundwater sources of drinking water quality?

New Hampshire is Different

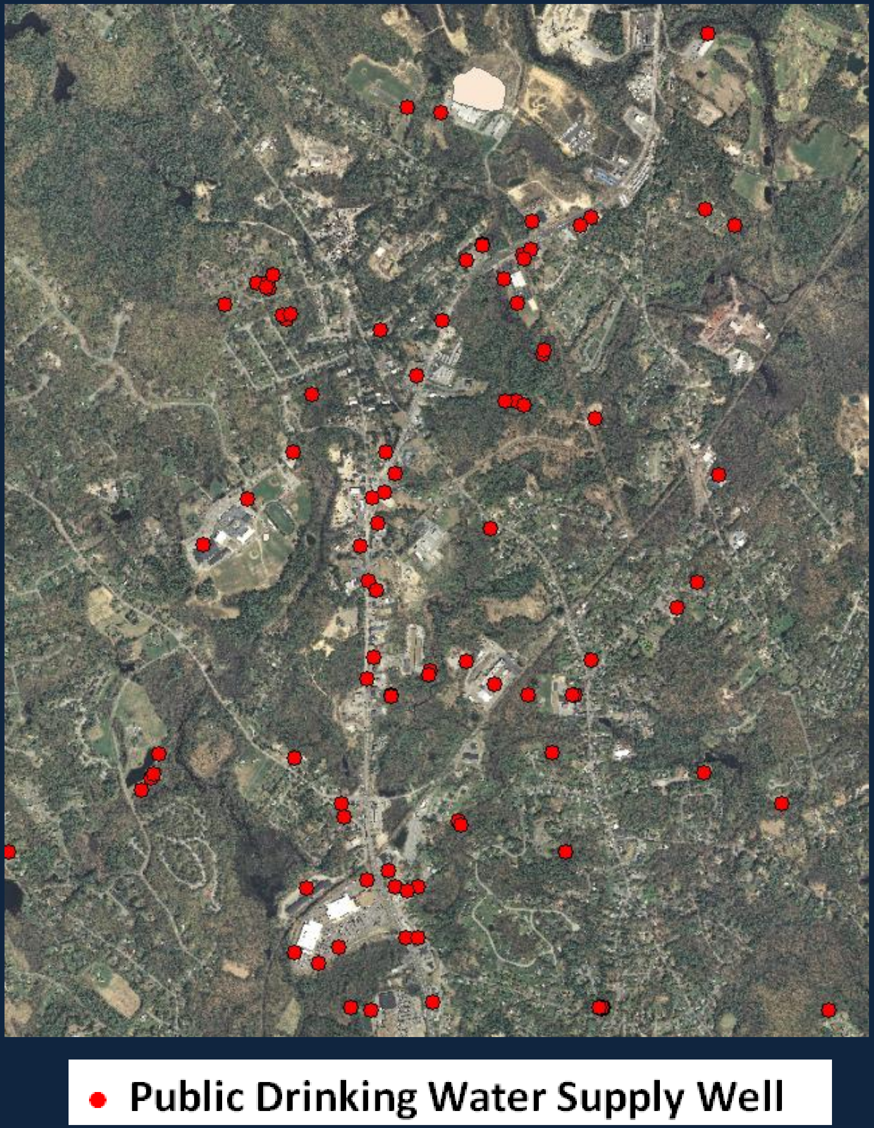
Drinking water sources are more numerous than other states



• Public Drinking Water Supply Well

New Hampshire is Different

Drinking water sources are decentralized and often located in developed areas – right where recharge occurs



Decentralized Drinking Water Sources and Stormwater Management

Developments often need to meet drinking water supply, stormwater, and wastewater needs all on one lot

Stormwater Impacts on Drinking Water Quality - Available Information

- Published Literature
- Public Water System Compliance Sampling Water Quality Data
- Unregulated Contaminant Monitoring Rule

Published Literature

- Impurities in road salt
- Road salt impacts on subsurface geochemistry
- Assess water quality up and down gradient of stormwater discharge/recharge
- Study the occurrence of <u>regulated</u> contaminants in asphalt and sealcoat in surface water
- Identify potential contaminants in stormwater

Granato's/USGS'1995 & 1996 Salt Studies

Mobilization of Major and Trace Constituents of Highway Runoff in Groundwater Potentially Caused by Deicing Chemical Migration

Gregory E. Granato, Peter E. Church, and Victoria J. Stone

Reprinted from
TRANSPORTATION RESEARCH RECORD 1483 (1995)
Transportation Research Board
National Research Council
Washington, D.C.

Subsurface Chemical RXNs and Impurities

Deicing Chemicals as Source of Constituents of Highway Runoff

Gregory E. Granato

Reprinted from
TRANSPORTATION RESEARCH RECORD 1533 (1996)
Transportation Research Board
National Research Council
Washington, D.C.

Impurities in Road Salt

Concentrations of Chloride and Sodium in Groundwater in New Hampshire From 1960 Through 2011

Median chloride concentrations were at least 1½ times higher and sodium concentrations at least 3 times higher between 2000–11 than in all previous decades.

Prepared in cooperation with the New Hampshire Department of Environmental Services

Concentrations of Chloride and Sodium in Groundwater in New Hampshire From 1960 Through 2011

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Introduction

Several studies from the 1970s and more recently (for example, Hall (1975), Daley and others (2009), and Mullaney (2009)) have found that concentrations of chloride and sodium in groundwater in New Hampshire have increased during the past 50 years. Increases likely are related to road salt and other anthropogenic sources, such as septic systems, wastewater, and contamination from landfills and salt-storage areas. According to water-quality data reported to the New Hampshire Department of Environmental Services (NHDES), about 100 public water systems (5 percent) in 2010 had at least one groundwater sample with chloride concentrations that were equal to or exceeded the U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant level (SMCL) of 250 milligrams per liter (mg/L) before the water was treated for public consumption. The SMCL for chloride is a measurement of potential cosmetic or aesthetic effects of chloride in water. High concentrations of chloride and sodium in drinking-water sources can be costly to remove.

A new cooperative study between the U.S. Geological Survey (USGS) and the NHDES (Medalie, 2012) assessed chloride and sodium levels in groundwater in New Hampshire from the 1960s through 2011. The purpose of the study was to integrate all data on concentrations of chloride and sodium from groundwater in New Hampshire available from various Federal and State sources, including from the NHDES, the New Hamsphire Department of Health and Human Services, the USGS, and the U.S. Environmental Protection Agency (USEPA), for public and private (domestic) wells and to organize the data into a database. Medalie (2012) explained the many assumptions and limitations of disparate data that were collected to meet wide-ranging objectives. This fact sheet summarizes the most important findings of the data.

The amount of a substance present in a given volume of water is often expressed as a concentration in mg/L.

The U.S. Environmental Protection Agency drinking water regulations specify the following:

- Chloride: SMCL of 250 mg/L
- Sodium: DWA for individuals on a sodium-restricted diet of 20 mg/L

Chloride

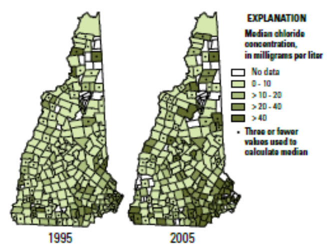


Figure 1. Median concentrations of chloride in groundwater in New Hampshire, using well data reported in 1995 and 2005. Differences between the maps illustrate changes in chloride concentrations by town. Towns with three or fewer values are flagged so the reader can get a sense of the distribution of data abundance. For this comparison, 687 records were used out of the 41,500 chloride records assembled for this project.

Overview of Significant Findings

Individual wells that had concentrations reported in both 1995 and 2005 were used to subset the data to show meaningful changes over time. The comparison of median concentrations of chloride (fig. 1) and sodium (fig. 2) by town for 1995 and 2005 shows a shift towards increased concentrations in 2005. The median is the middle value in the dataset after the data have been ordered by magnitude. Between 1995 and 2005, the number of towns with median concentrations of chloride greater than 20 mg/L almost doubled from 35 to 65, and the number of towns with concentrations of chloride greater than 40 mg/L more than tripled from 10 to 34. Over the same time span, the number of towns with concentrations of sodium greater than 10 mg/L increased from 89 to 114, and the number of towns with concentrations greater than 20 mg/L increased from 26 to 43. The numbers themselves are not as important as their utility in describing increases over time.

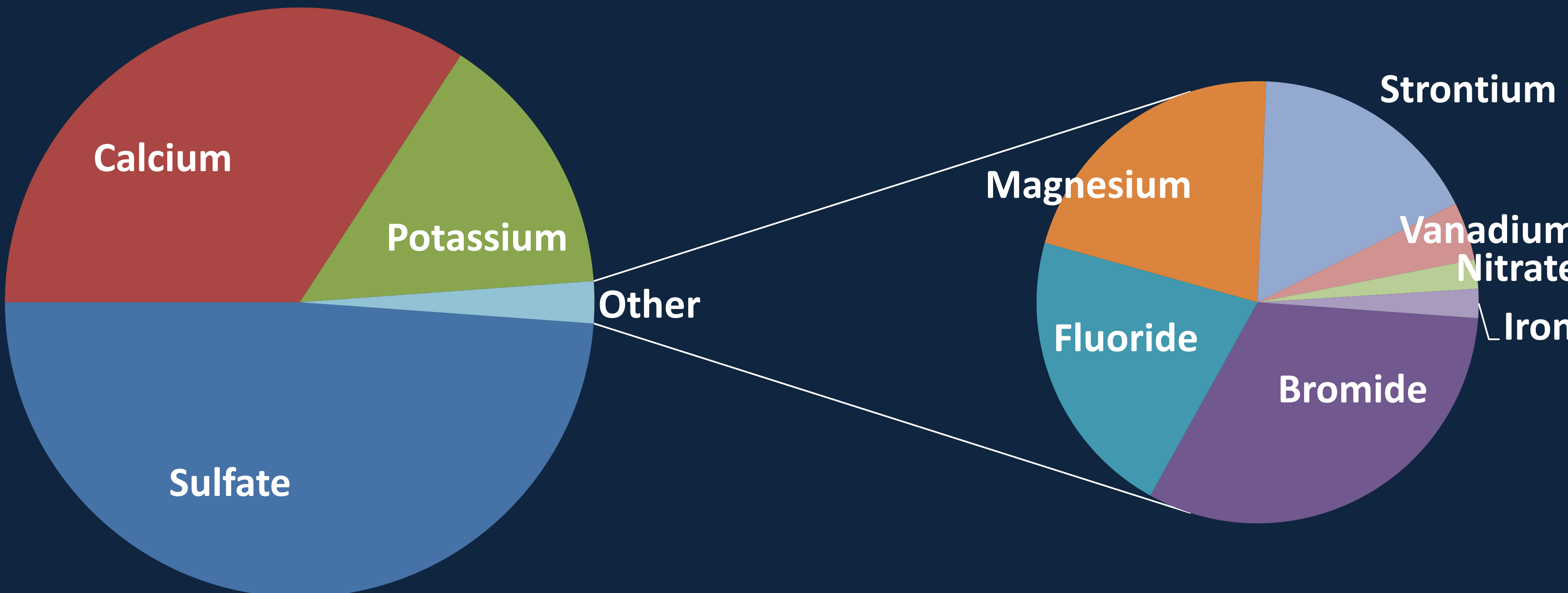
Table 1 shows that the 17 mg/L median concentration of chloride in the 2000s was at least one and a half times higher than the median for all previous decades. The 90th percentile (highest 10 percent of values) of concentration for 2000–11 was higher than for all decades and double all the values for the 1980s and 1990s. Low concentrations among decades, shown by the 10th percentile (lowest 10 percent of values), cannot be compared because many of the reported values were below a reporting threshold (indicated with "<"). To compare data with different reporting thresholds, all values below the reporting threshold (censored values) were adjusted to the common value of 10 mg/L, which was the highest censored value among the data.

Most of the percentiles of concentrations of sodium for data through the 1990s were less than 10 mg/L; however, all the percentiles were greater than 10 mg/L in the 2000s. Between the 1990s and 2000s, all percentiles of concentrations of sodium increased—the median by more than a factor of three, and the 90th percentile by a factor of six. These data provide substantial evidence that sodium concentrations in New Hampshire groundwater for 2000–11 increased considerably from previous decades.

Photograph by Steven Corsi, U.S. Geological Survey

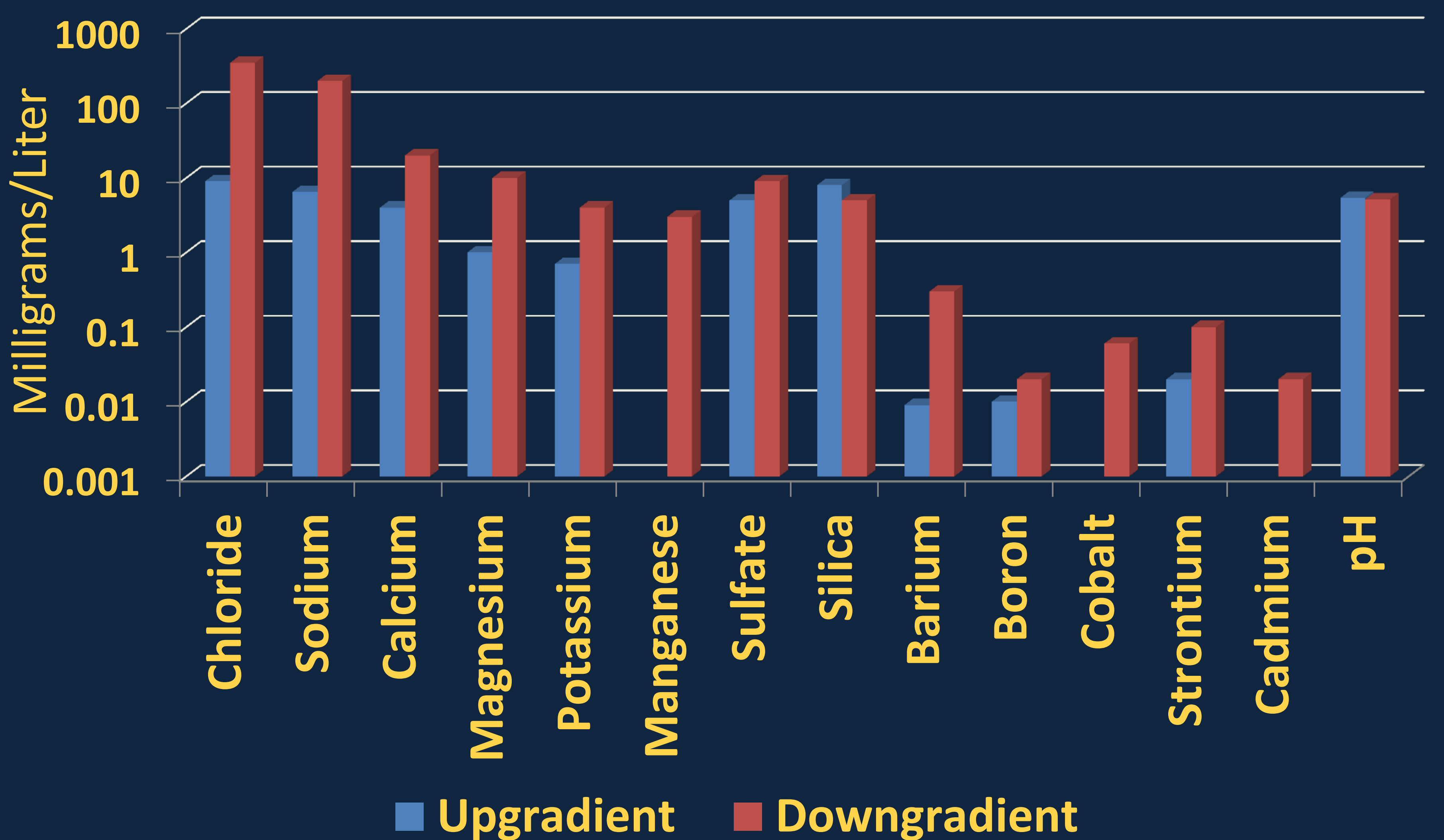
USGS Factsheet 2013-3011

Road Salt is 95%-98% Pure NaCl
Relative Mass of Impurities in Road Salt



Data obtained from Granato's 1996 Study

Groundwater Quality Upgradient and Downgradient of Salt Treated Roadway



Data obtained from Granato's 1995 Study

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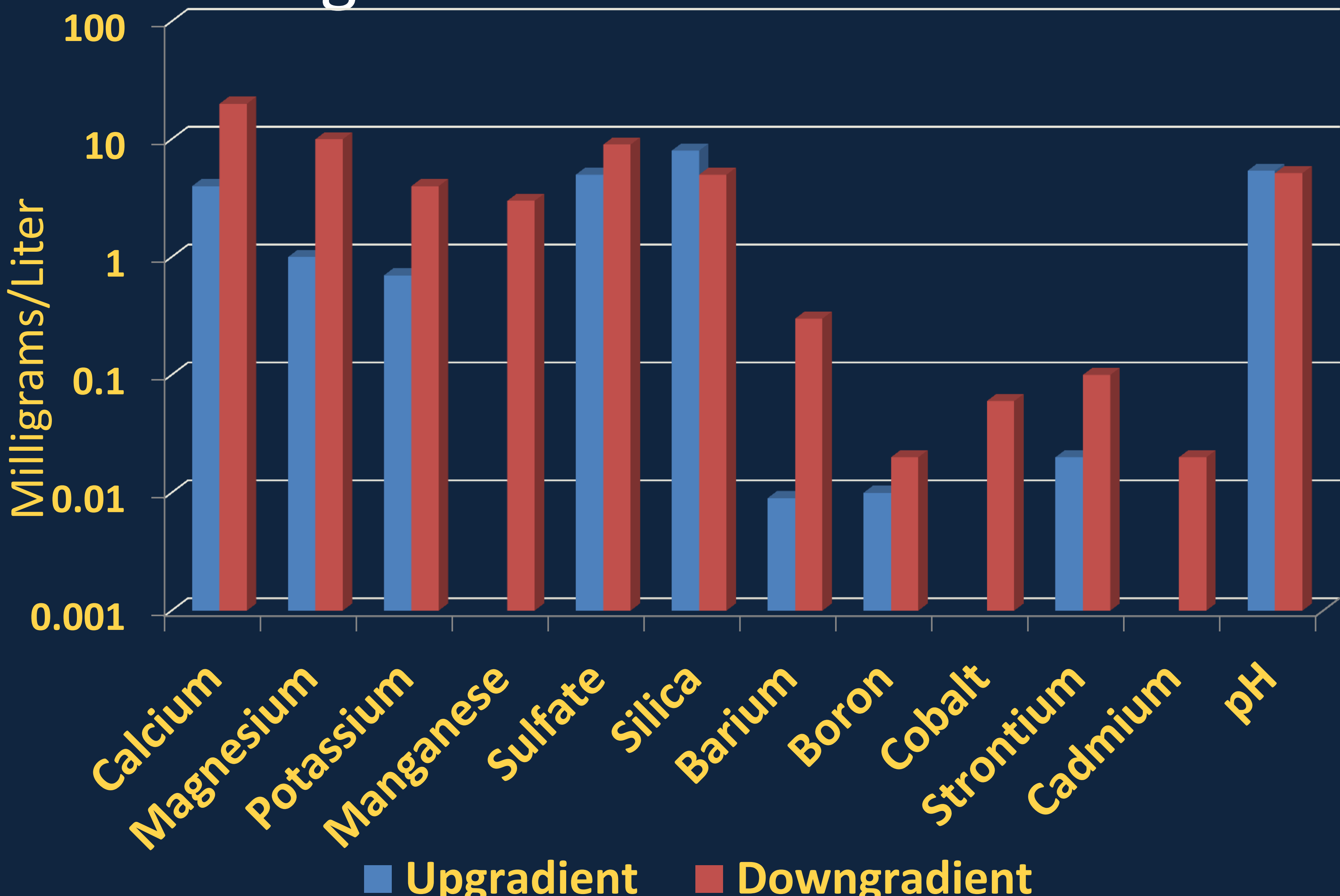
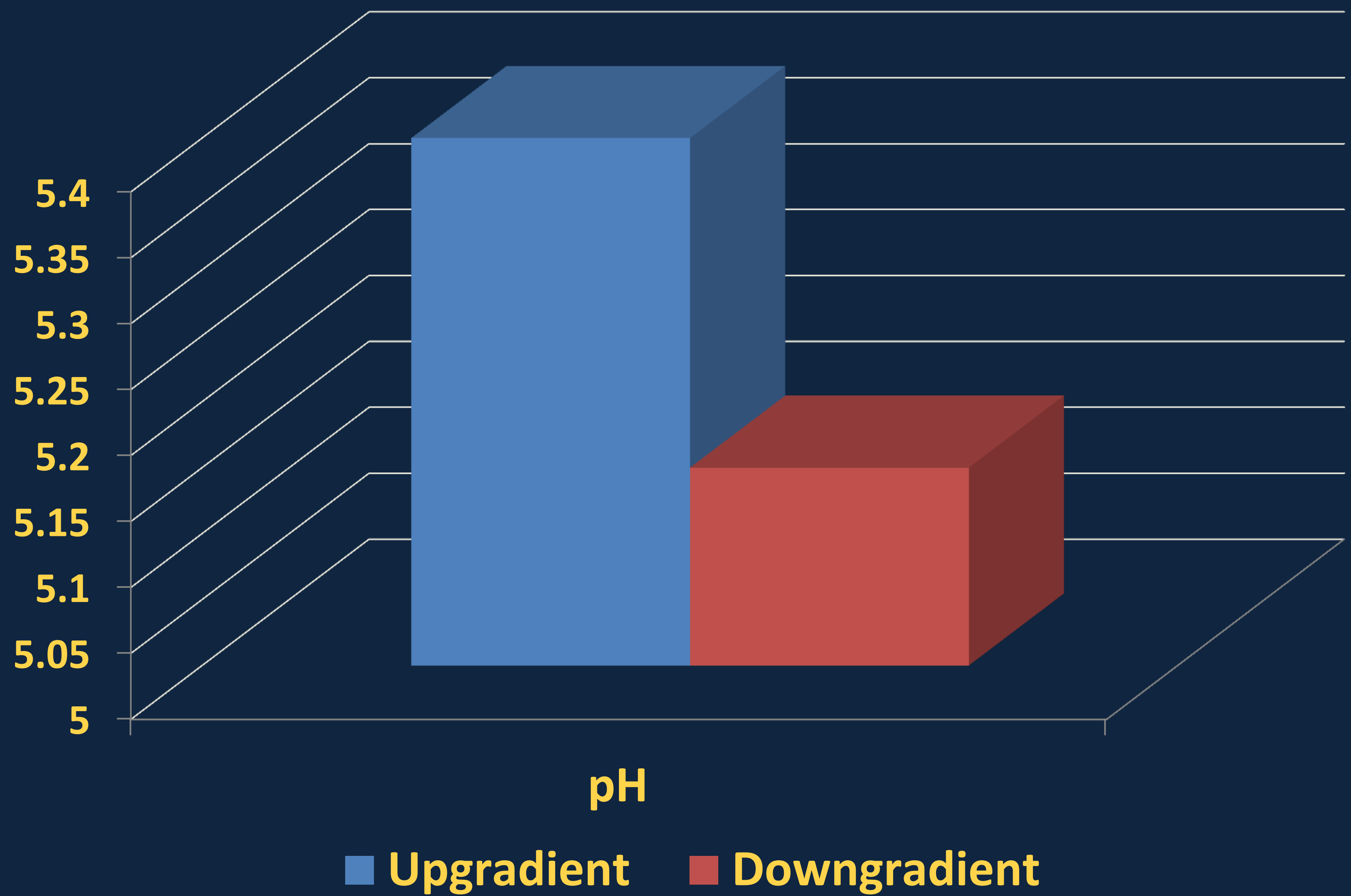


Data obtained from Granato's 1995 Study

pH
2x As Many Hydrogen Ions Downgradient



Data obtained from Granato's 1995 Study

Other Potential Pollutants in Stormwater

- Asphalt/Sealcoat/Motor Oil/Gasoline Contaminants
  - Organic Compounds
  - Heavy Metals
  - Gasoline
- Landscape Nutrients
  - Nitrate/Nitrite
  - Pesticides

Groundwater Protection Council
http://www.gwpc.org/sites/default/files/files/Stormwater%20Management%20Full%20Chapter.pdf

“Other Pollutants” in Stormwater/ Impacts on Groundwater

- Groundwater quality not rigorously studied
- Impacts are often
  - Generalized based on intuition
  - Thought to be “offset” by quantity benefits
  - Not contemplated in the context of thousands of decentralized drinking water sources.
  - Not contemplated beyond currently regulated contaminants

USGS
science for a changing world

Texas Water Science Center

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Sealcoat: Home | What is Sealcoat? | Publications | Photo Gallery

Coal-tar-based sealcoat being applied to a test plot.

Quick Questions

- What is pavement sealcoat?
- What are PAHs?
- What are coal tar and coal tar pitch?

PAH and Sealcoat Contacts

Barbara Mahler
USGS Research Hydrologist
(512) 927-3566

Peter Van Metre
USGS Research Hydrologist
(512) 927-3506

Mailing Address:
U.S. Geological Survey
1505 Ferguson Lane
Austin, TX 78754

PAHs and Coal-Tar-Based Pavement Sealcoat

Coal-tar-based pavement sealant is a potent source of polycyclic aromatic hydrocarbons (PAHs), as documented by the USGS and other researchers.

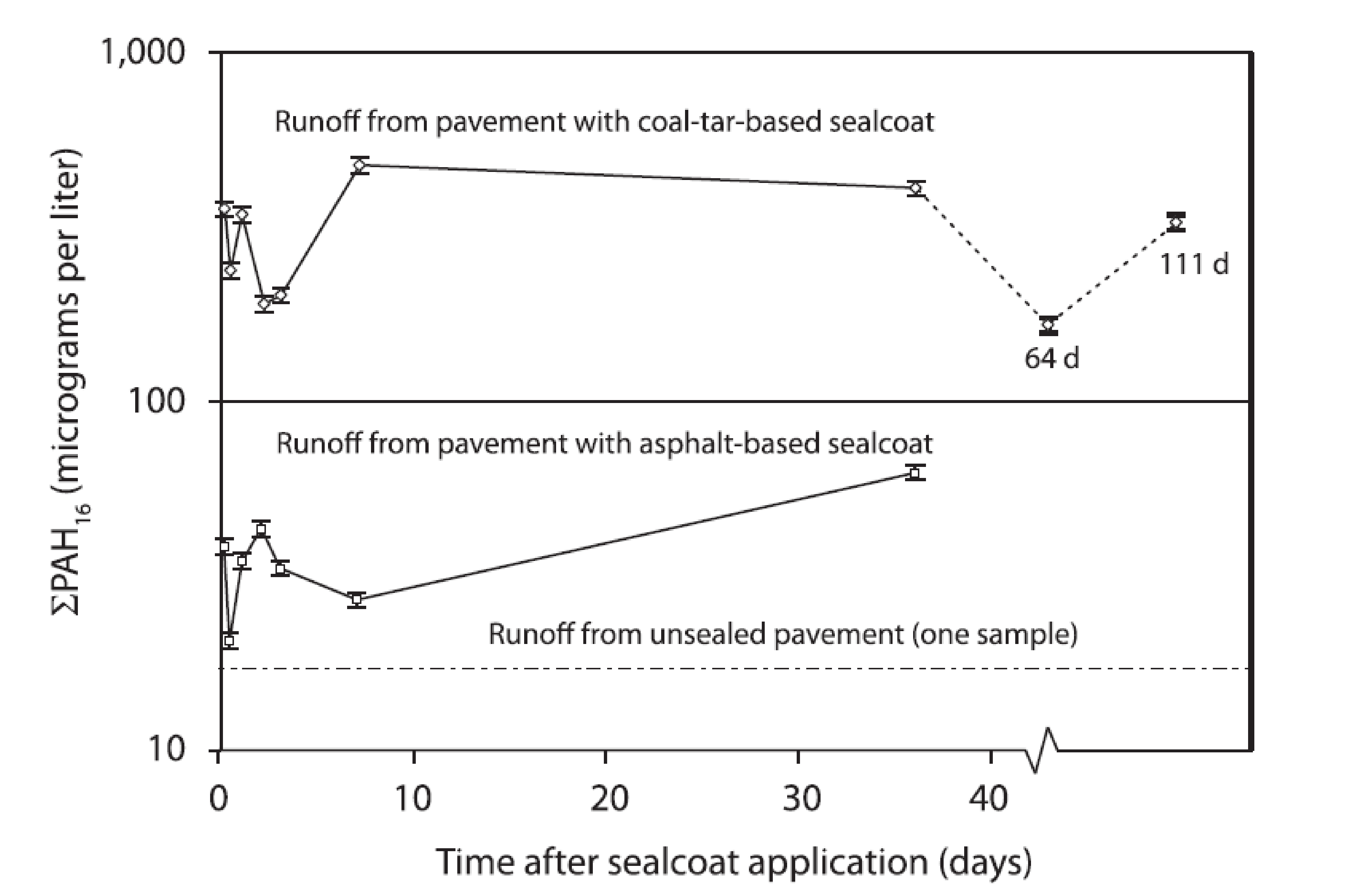
Coal-tar-based sealcoat products typically are 20 to 35% coal tar or coal-tar pitch—these materials are known human carcinogens that contain high concentrations of PAHs and related chemicals. Coal-tar-based pavement sealcoat typically contains 35,000 to 200,000 mg/kg (parts per million, or ppm) PAHs, about 100 times more PAHs than in used motor oil and about 1,000 times more PAHs than in sealcoat products with an asphalt base.

Coal-tar sealcoat is abraded to a fine dust by car tires and snow plows, requiring reapplication every 2–5 years. The mobile high-PAH dust is blown, washed, or tracked into nearby soil, stormwater ponds, streams, lakes, and house dust. Many of the lighter-weight chemicals in coal-tar sealcoat volatilize (evaporate) into the air, primarily during the 2 weeks following application, but continuing for years after application.

Learn more about PAHs and coal-tar-based sealcoat

- Coal-Tar-Based Pavement Sealcoat, Polycyclic Aromatic Hydrocarbons (PAHs), and Environmental Health (USGS factsheet, 2011) and
- Coal-Tar-Based Pavement Sealcoat and PAHs: Implications for the Environment, Human Health, and Stormwater Management (Environmental Science & Technology feature article, 2012).
- Additional peer-reviewed journals, USGS publications, and presentations

NH Generally Uses Coal Tar Sealcoats



Mahler, B. J.; Van Metre, P. C.; Foreman, W. T., Concentrations of polycyclic aromatic hydrocarbons (PAHs) and azaarenes in runoff from coal-tar- and asphalt-sealcoated pavement. Envion. Pollut. 2014, 188, 81-87.

Laying it down, testing it later

Fall 2014 Article from the Commonwealth Magazine

- Various chemicals are added to asphalt
- Recently, as much as 8% of asphalt consisted of recycled engine oil. NH was not informed of this

"There are no prohibitions on what binders an asphalt producer can use unless a state specifically bans an additive."

Workers lay down asphalt on Union Street in Hingham, one of many road projects using asphalt containing recycled engine oil.

Legal Challenge to the Use of Recycled Engine Oil

- NH issued a ban on the use of recycled engine oil in asphalt based on performance concerns not environmental questions
- Ban has been initially upheld in Court
- Does not affect the use of coal tar sealcoats

The State of New Hampshire

MERRIMACK, SS **SUPERIOR COURT**

Bitumar USA, Inc.

v.

New Hampshire Department of Transportation

NO. 217-2014-CV-00389

ORDER

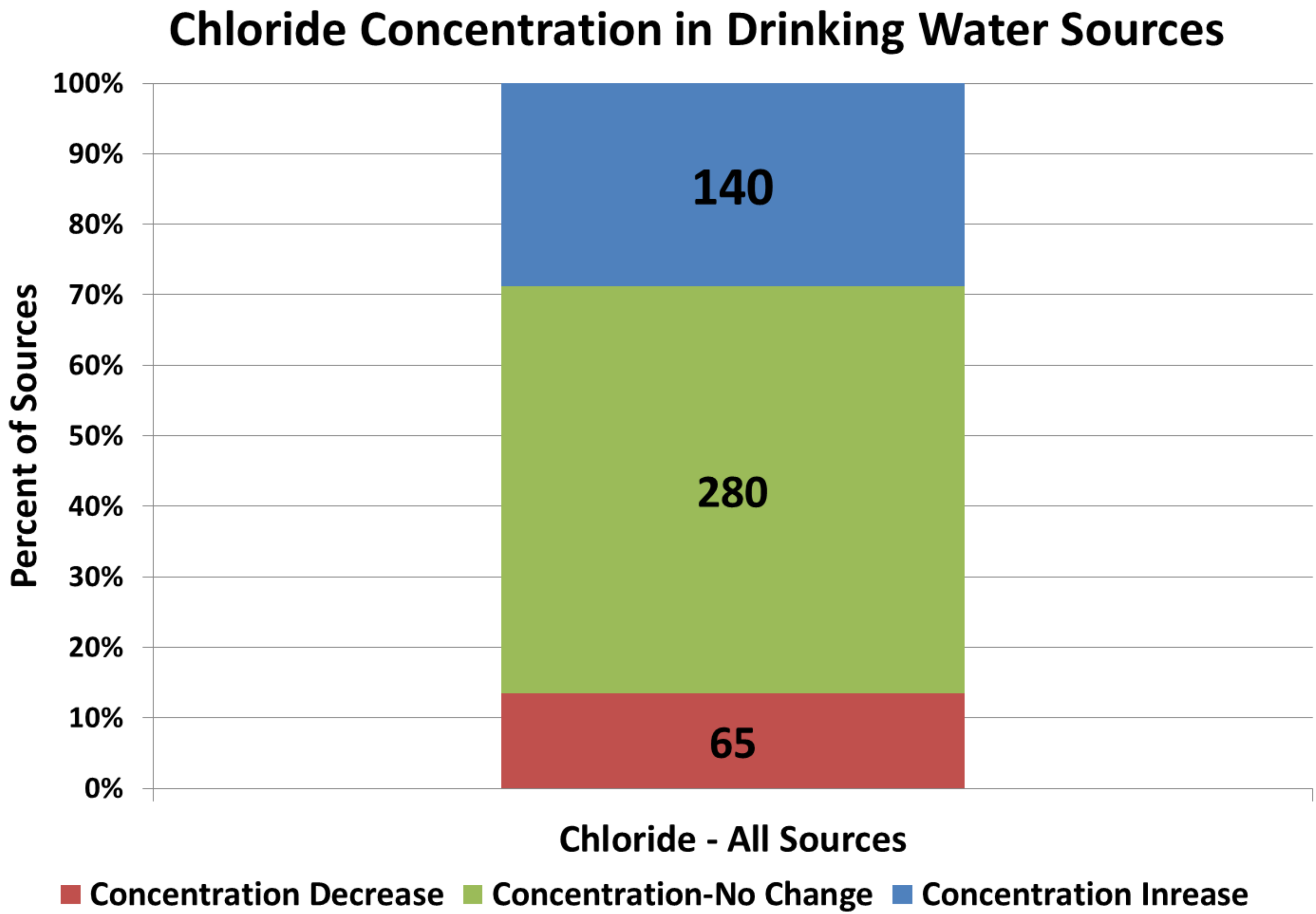
Assessing Water Quality Trends Using Public Water Supply Compliance Data

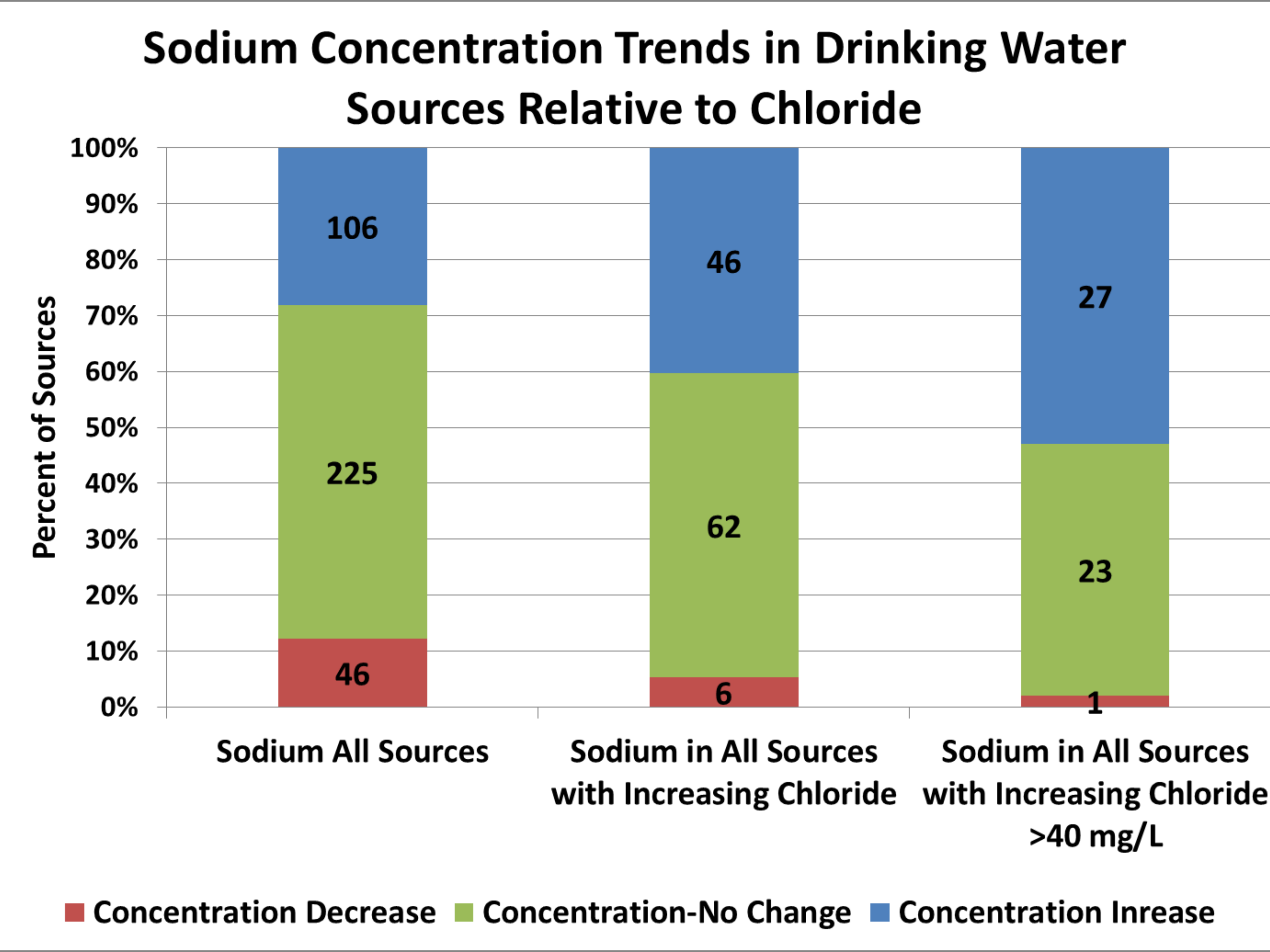
Data is challenging for research purposes

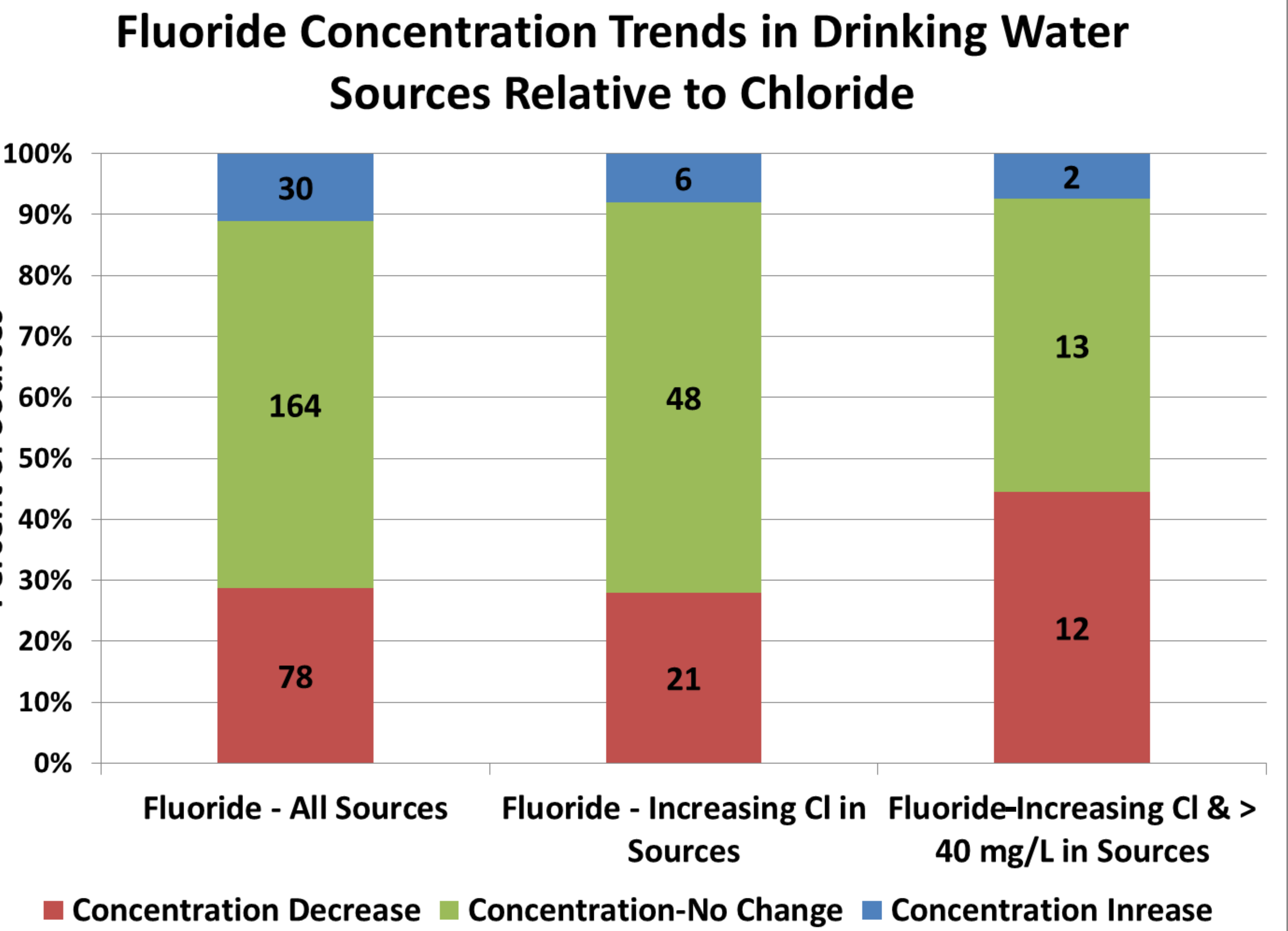
- "Non Detects"
- Different constituents are sampled for on different days/different seasons/different years
- Constituents are monitored relatively infrequently/Generally 2-6 data points for each constituent per source are available in our database
- Can only use data from drinking water sources with no treatment (approximately 10% of all sources)

Study Approach

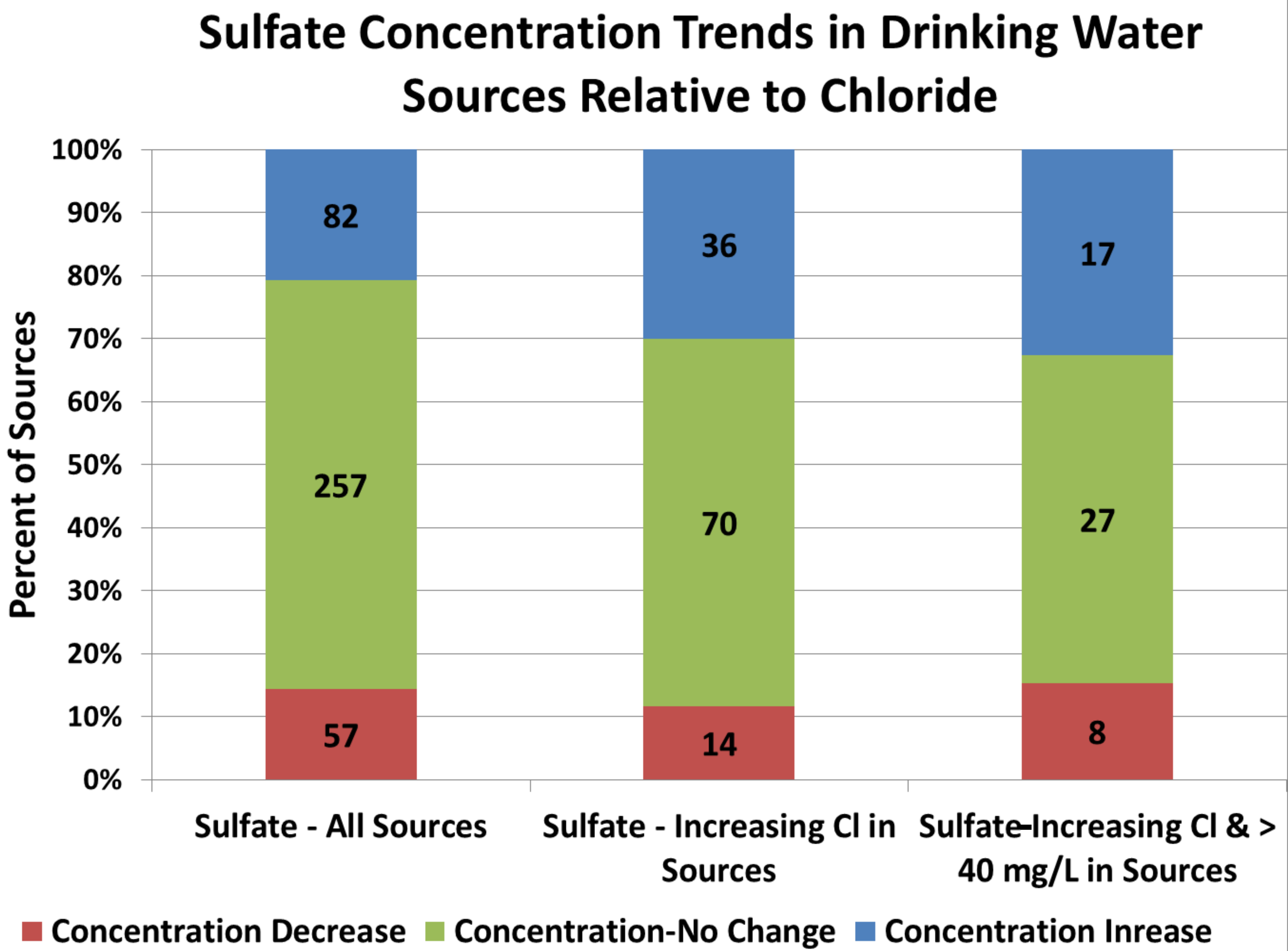
- Data from sources with no treatment
- Required three results per constituent/source
- Determined trends based on results being sequential (this is very conservative).
- ***Utilized elevated concentrations of chloride in sources as a tracer to indicate impacts from stormwater***


Chloride Concentration in Drinking Water Sources
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Sources
140
280
65
Chloride - All Sources
Concentration Decrease
Concentration-No Change
Concentration Inrease

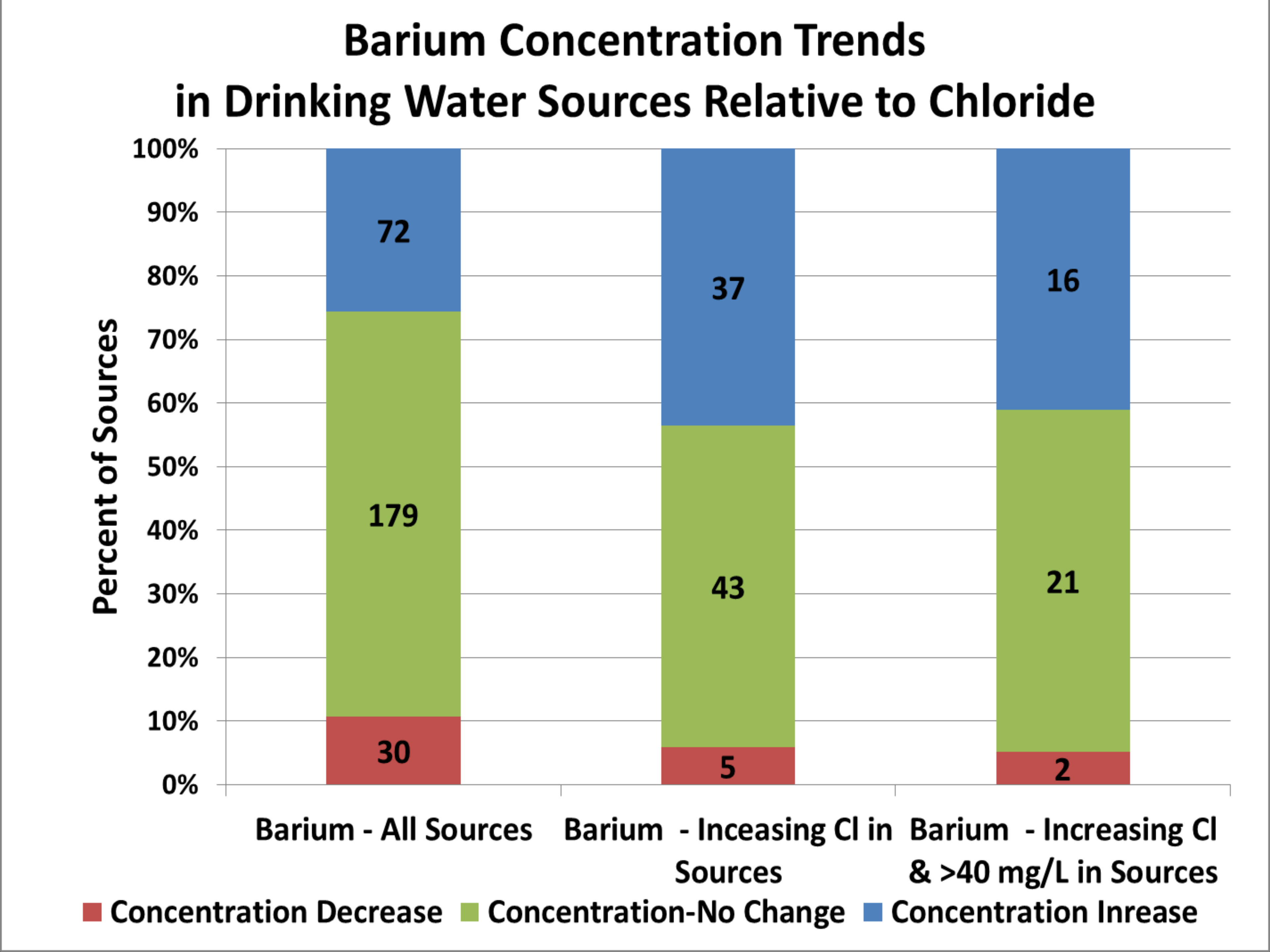

Sodium Concentration Trends in Drinking Water Sources Relative to Chloride
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Sources
106
225
46
46
62
6
27
23
1
Sodium All Sources
Sodium in All Sources with Increasing Chloride
Sodium in All Sources with Increasing Chloride >40 mg/L
Concentration Decrease
Concentration-No Change
Concentration Inrease

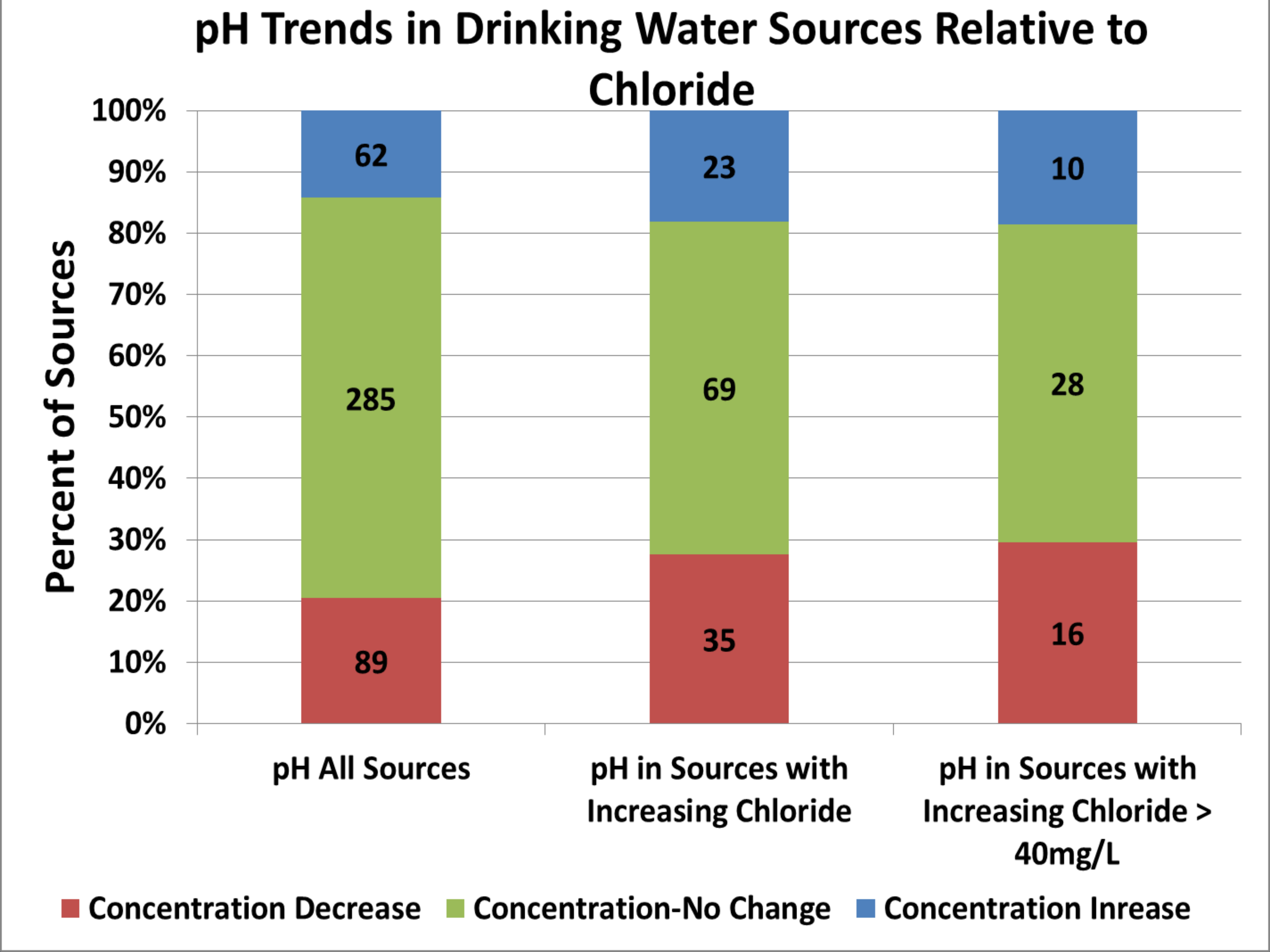


Fluoride Concentration Trends in Drinking Water Sources Relative to Chloride
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
30
164
78
6
48
21
2
13
12
Fluoride - All Sources
Fluoride - Increasing Cl in Sources
Fluoride–Increasing Cl & > 40 mg/L in Sources
Concentration Decrease
Concentration-No Change
Concentration Inrease



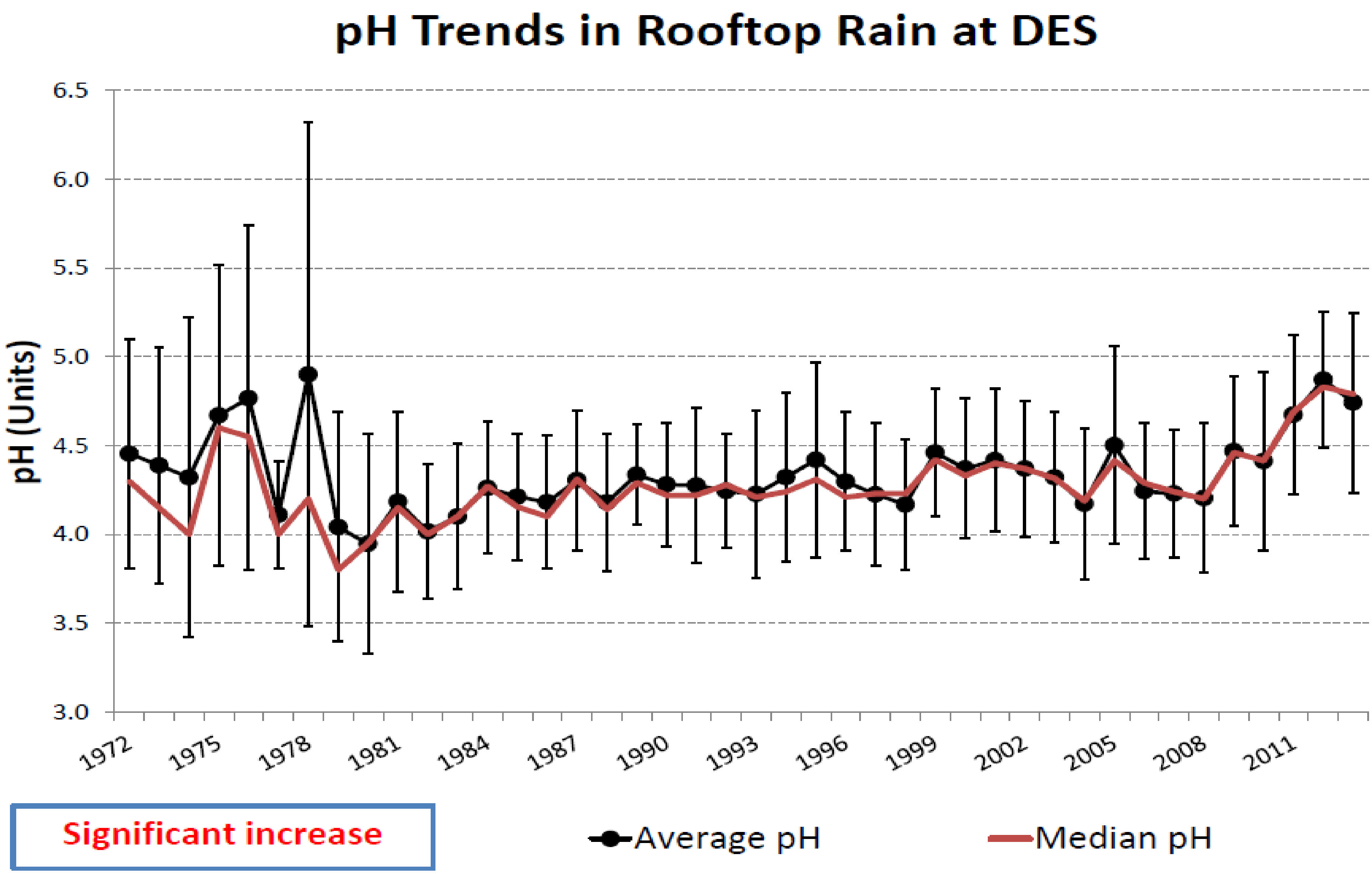
Sulfate Concentration Trends in Drinking Water Sources Relative to Chloride
Percent of Sources
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
82
257
57
36
70
14
17
27
8
Sulfate - All Sources
Sulfate - Increasing Cl in Sources
Sulfate-Increasing Cl & > 40 mg/L in Sources
Concentration Decrease
Concentration-No Change
Concentration Inrease

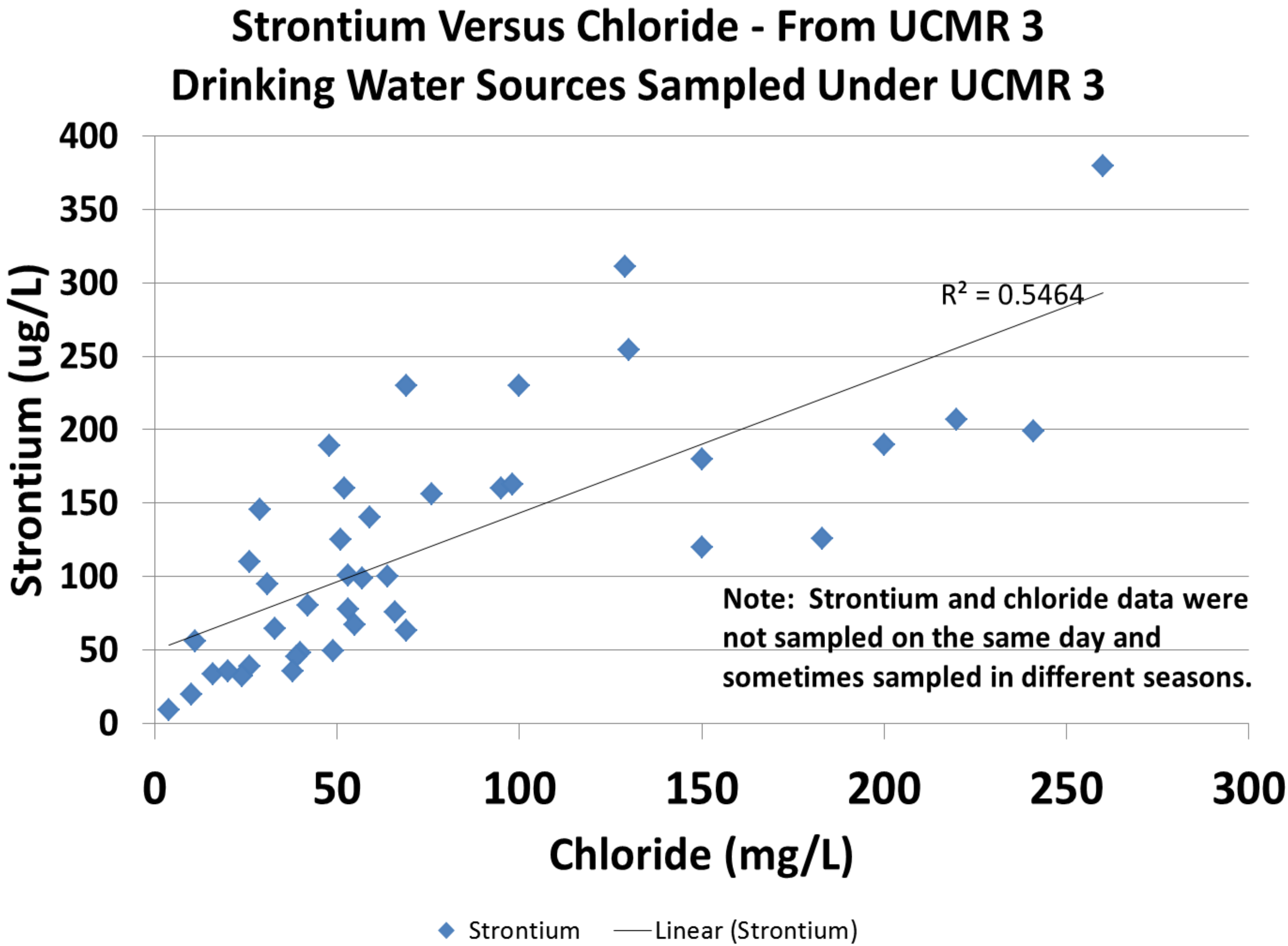

Barium Concentration Trends
in Drinking Water Sources Relative to Chloride
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Sources
72
179
30
37
43
5
16
21
2
Barium - All Sources
Barium - Inceasing Cl in Sources
Barium - Increasing Cl & >40 mg/L in Sources
Concentration Decrease
Concentration-No Change
Concentration Inrease



pH Trends in Drinking Water Sources Relative to Chloride
Percent of Sources
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
62
285
89
23
69
35
10
28
16
pH All Sources
pH in Sources with Increasing Chloride
pH in Sources with Increasing Chloride > 40mg/L
Concentration Decrease
Concentration-No Change
Concentration Inrease

There could be other thinks impacting the pH of Drinking Water…………



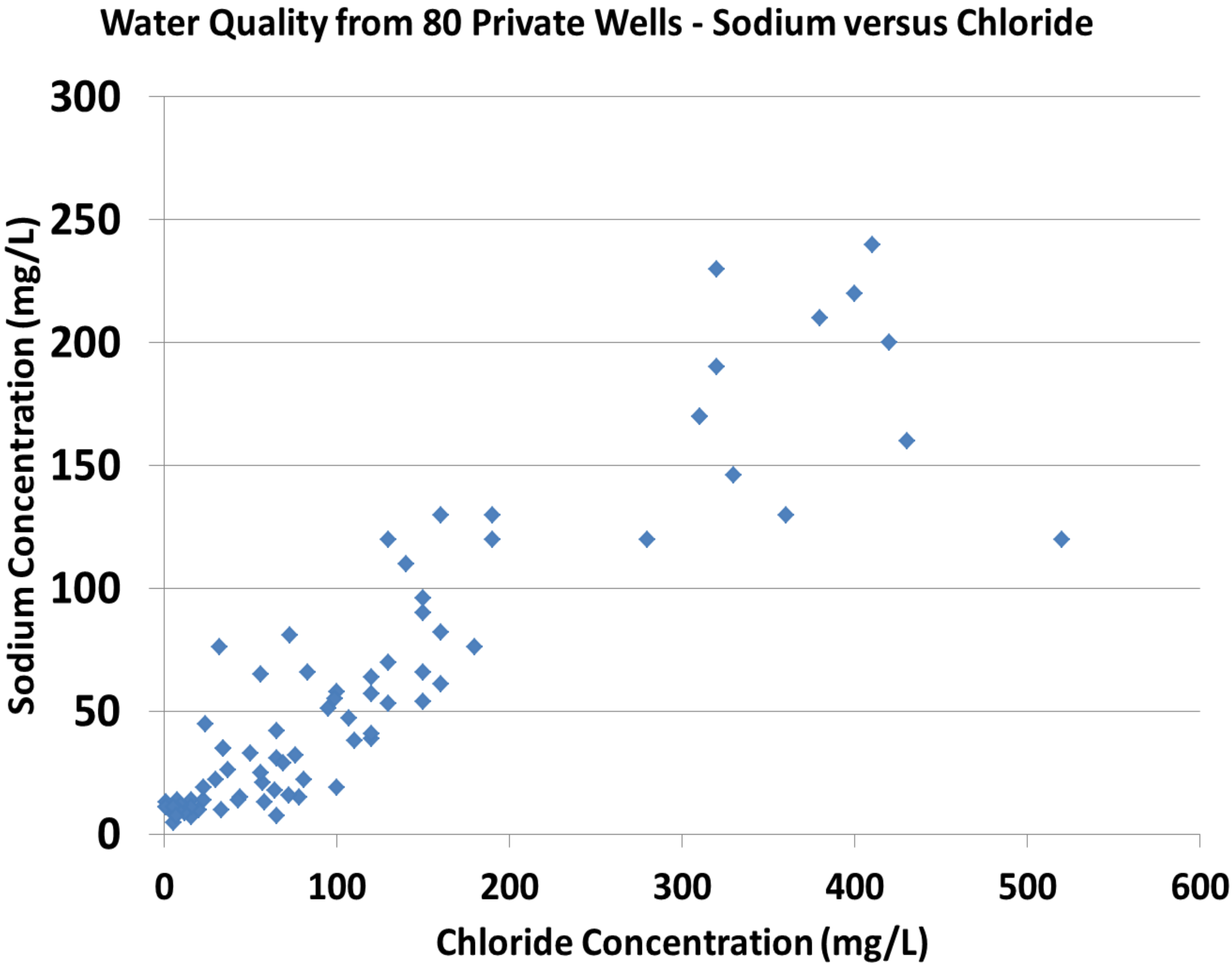

Strontium Versus Chloride - From UCMR 3
Drinking Water Sources Sampled Under UCMR 3
Strontium (ug/L)
400
350
300
250
200
150
100
50
0
0
50
100
150
200
250
300
Chloride (mg/L)
R^2 = 0.5464
Note: Strontium and chloride data were not sampled on the same day and sometimes sampled in different seasons.
Strontium
Linear (Strontium)

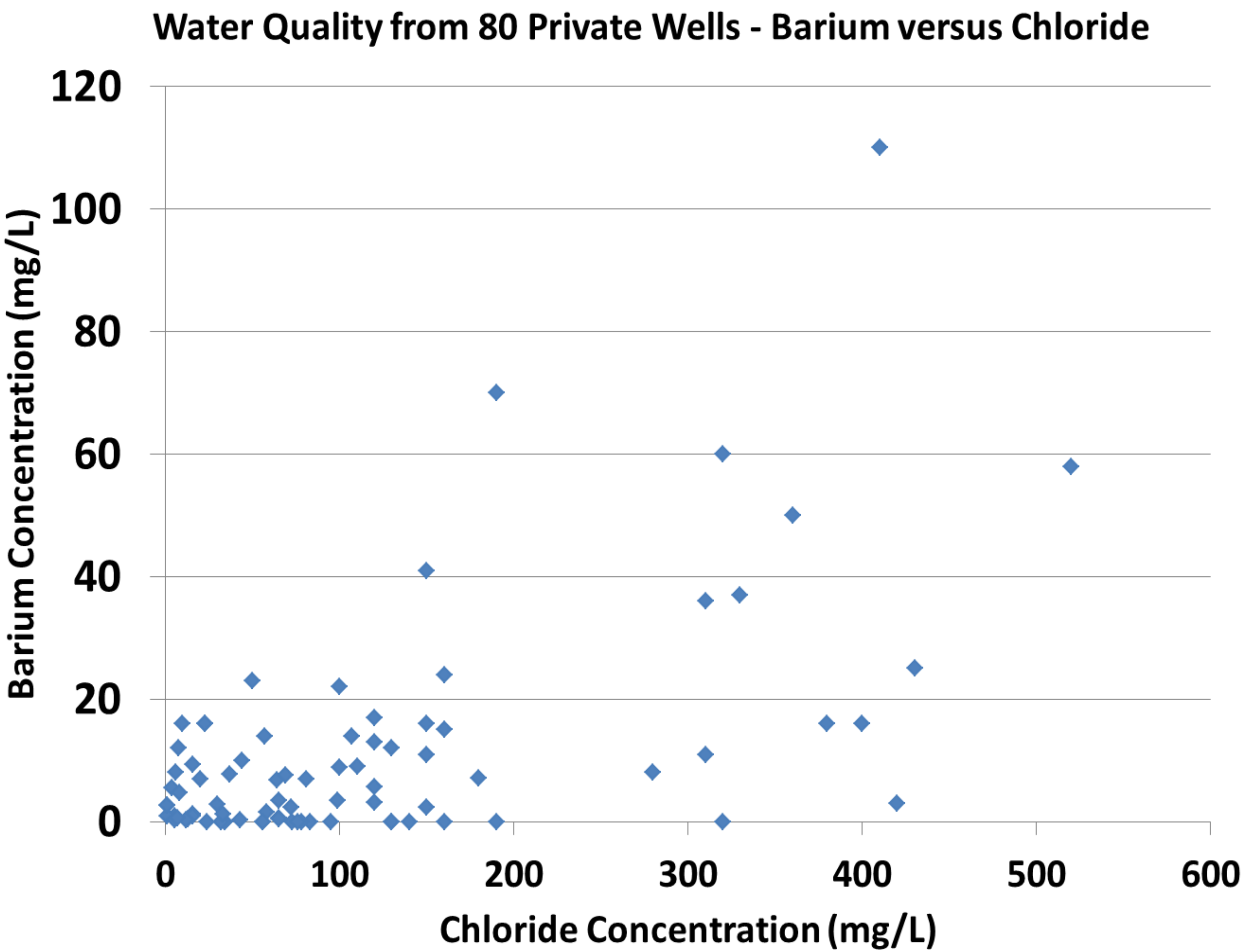
Other UCMR Data

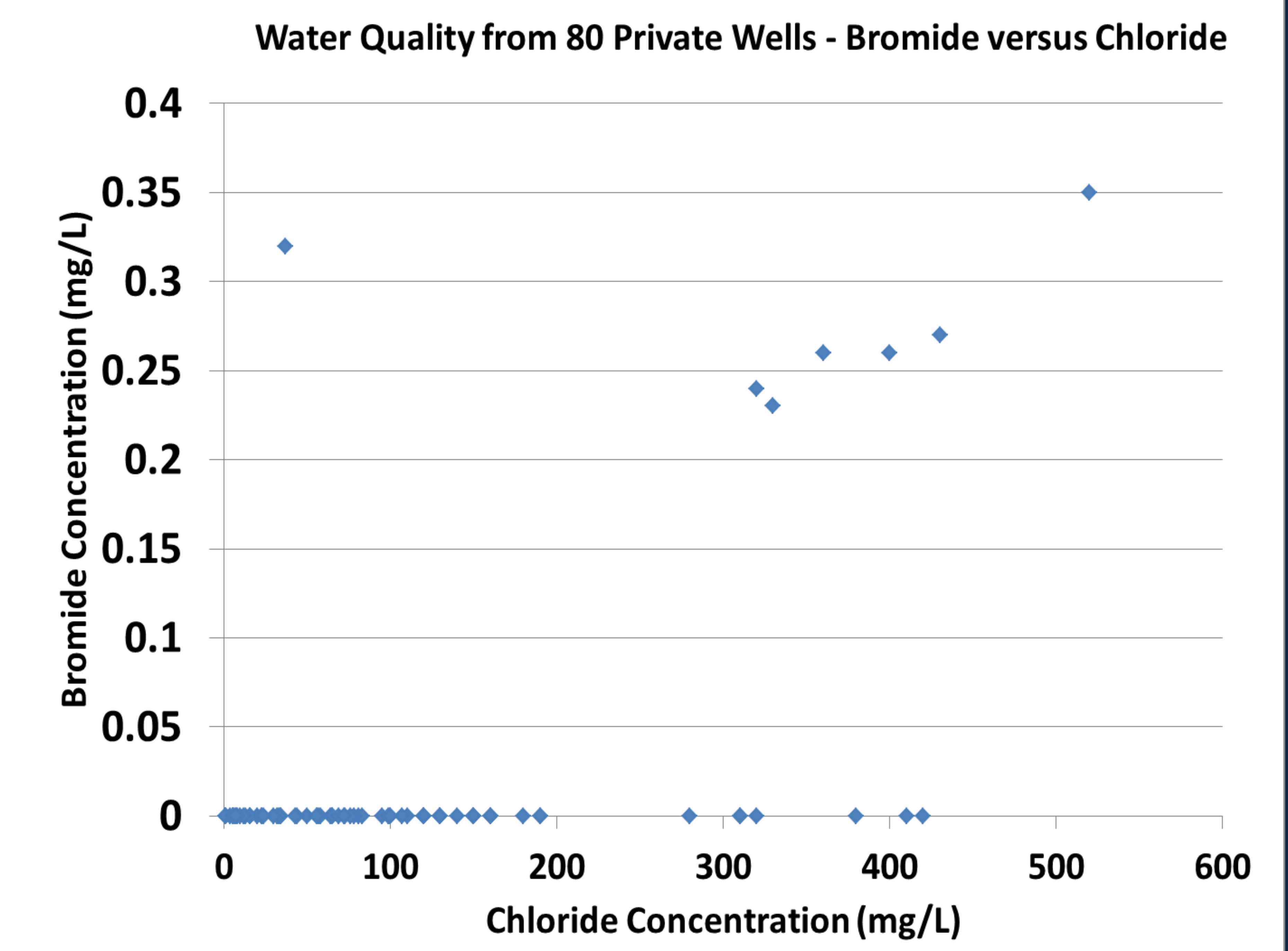
Parameters that did not correlate with the occurrence of road salt:

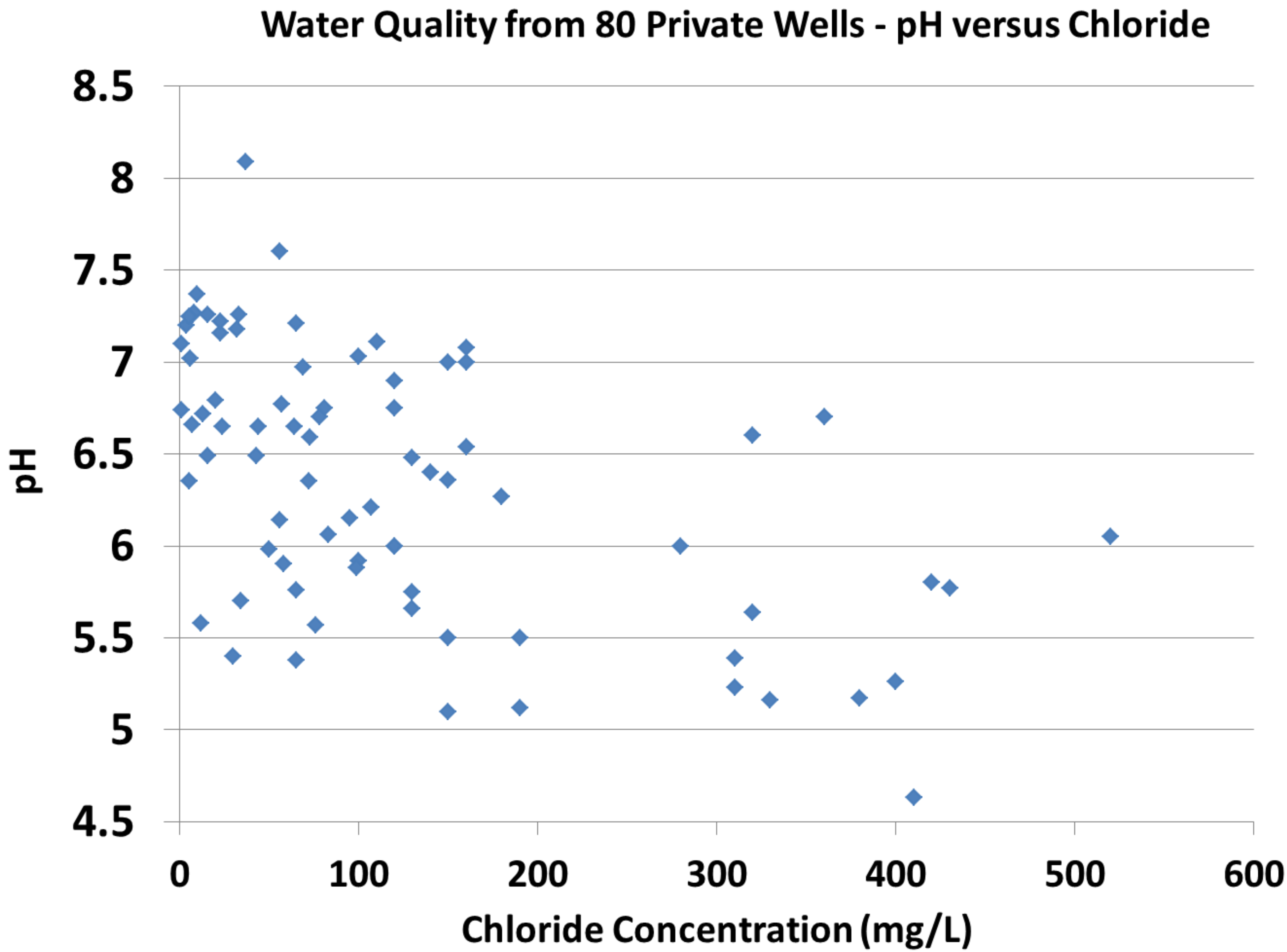
- Chromium
- Chromium VI
- Vanadium
- Cobalt

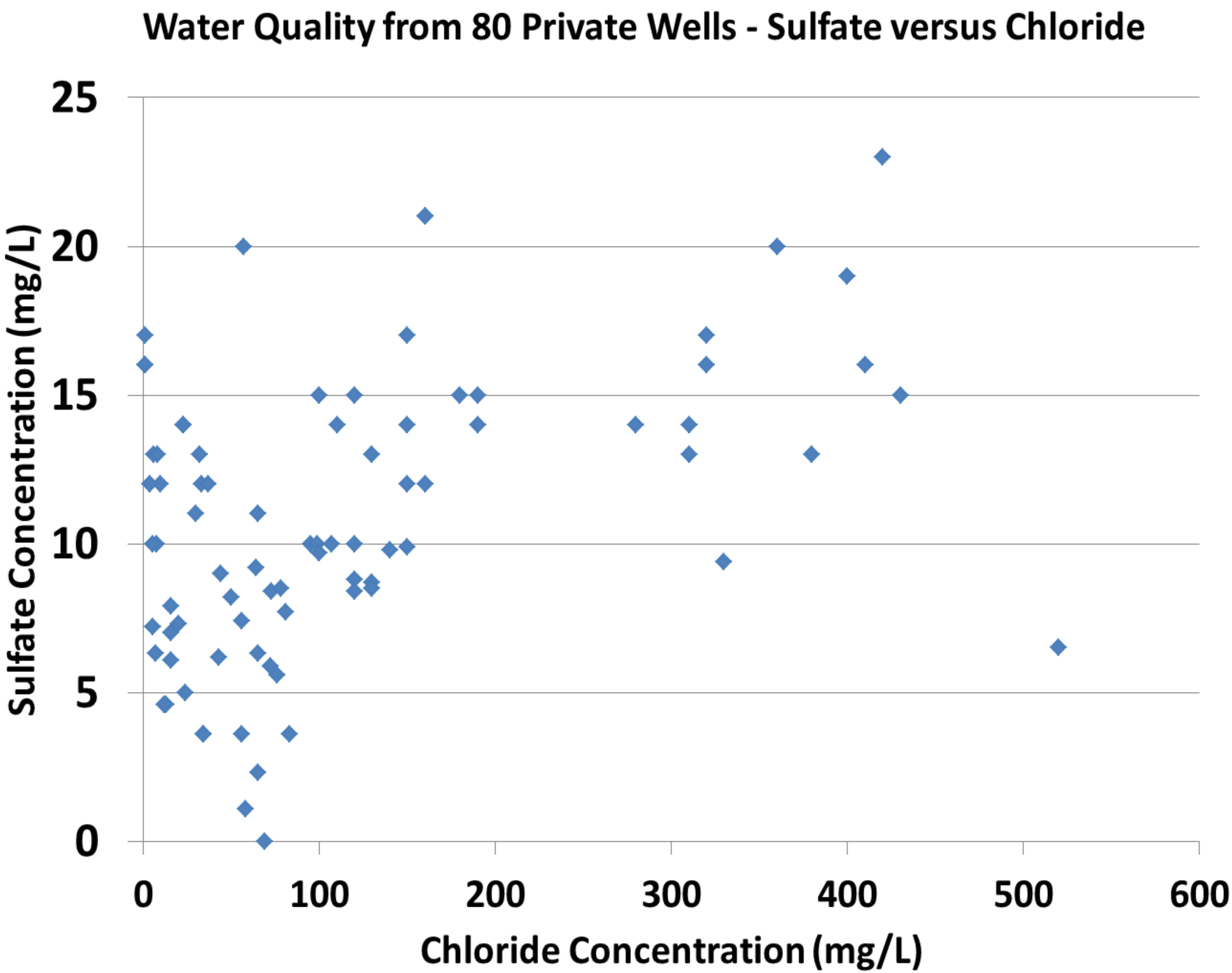
UCMR Data is skewed because most data is from very large water systems with well protected water sources.


Water Quality from 80 Private Wells - Sodium versus Chloride
Sodium Concentration (mg/L)
300
250
200
150
100
50
0
0
100
200
300
400
500
600
Chloride Concentration (mg/L)


Water Quality from 80 Private Wells - Barium versus Chloride
Barium Concentration (mg/L)
0
20
40
60
80
100
120
0
100
200
300
400
500
600
Chloride Concentration (mg/L)


Water Quality from 80 Private Wells - Bromide versus Chloride
Bromide Concentration (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
100
200
300
400
500
600
Chloride Concentration (mg/L)


Water Quality from 80 Private Wells - pH versus Chloride
8.5
8
7.5
7
6.5
6
5.5
5
4.5
pH
0
100
200
300
400
500
600
Chloride Concentration (mg/L)


Water Quality from 80 Private Wells - Sulfate versus Chloride
Sulfate Concentration (mg/L)
0
5
10
15
20
25
0
100
200
300
400
500
600
Chloride Concentration (mg/L)

Volatile and Semi-Volatile Organic Compounds

- Except for historic MtBE detections, these compounds have not routinely not been associated with stormwater
- 16 organic compounds associated with sealcoats are not regularly detected in any public water supply source due to stormwater infiltration
- Pesticides have not regularly been regularly detected in public water sources

Limitations to Volatile and Semi-Volatile Organic Compounds Data

- Only a subset of compounds in sealcoats are monitored
- Monitoring doesn’t not coincide with
  - Recharge events
  - The time that sealcoats are applied
- Pesticide results could be misleading. Need to assess breakdown products
- Should we look for these compounds below traditional detection limits?

Cyanide Based Additives in Road Salt

State of New Hampshire
Division of Plant and Property Management
Bureau of Purchase and Property
25 Capitol Street, State House Annex
Concord, NH 03301-6398

Date: June 17, 2014

Bid No.: 1626-14

Date of Bid Opening: June 27, 2014

Time of Bid Opening: 1:30 PM (EST)

YOU MAY EMAIL YOUR BID TO Laura Ingram AT: EMAIL PRCHWEB@NH.GOV

BID INVITATION FOR: **ROCK & SOLAR SALT**

[Insert name of signor] Anthony T. Patton, on behalf of Morton Salt, Inc. [insert name of entity submitting bid (collectively referred to as "Vendor") hereby submits an offer as contained in the written bid submitted herewith ("Bid") to the State of New Hampshire in response to **BID #1626-14** at the price(s) quoted herein in complete accordance with the bid.

Vendor attests to the fact that:

ANTI-CAKING ADDITIVE

Salt shall be loose and free of lumps and shall contain not less than 20 ppm of pure anti-caking agent. Bidders who are awarded contracts will be required to submit the appropriate Material Safety Data Sheets (MSDS) to NHDOT, OTHER STATE AGENCIES and Eligible Participants as requested

(BIDDER TO COMPLETE) Anti-Cake Additive: Sodium Ferrocyanide

PART Env-Dw 711 MONITORING FOR INORGANIC CHEMICALS

"(e) The department shall waive the requirement to monitor for cyanide if the department determines that the PWS is not vulnerable to cyanide due to a lack of any industrial source(s) within the wellhead contributing area."

Perchlorate

One study found low levels of perchlorate in road salt sampled from storage piles at concentrations of 64 and 7.8 µg/kg

J. Munster and G. N. Hanson, *Environ. Chem.* **2009**, *6*, 28–35. doi:10.1071/EN08085 www.publish.csiro.au/journals/env

Perchlorate and ion chemistry of road runoff

Jennie Munster[A,B] *and Gilbert N. Hanson*[A]

Infiltration of Stormwater/Impact on Drinking Water - Conclusions

- Can significantly impact chloride and sodium concentrations in groundwater

- Coincide with changes in the concentrations of multiple concentrations of metals and inorganic compounds
  - Changes have not cause and drinking water violations
  - Reaction of salt and the subsurface?
  - Impurities in road salt?
  - Salt in groundwater is an indicator of a more direct connection to recent recharge
    - Younger groundwater/Lower pH
    - More susceptible to contaminants on the land surface

Infiltration of Stormwater – Conclusions (continued)

- Data does not exist to determine the cumulative effect of recharging stormwater to groundwater.

- Additional siting criteria may need to be included when designing infiltration infrastructure
  - Type of asphalt/sealcoat needs to be added to Green Infrastructure Design BMPs
  - Distance and gradient to drinking water sources
  - Depth to bedrock
  - How much salt is in the groundwater in the area already? How much salt is too much? Salt offsets for new development that recharges stormwater?

Data Gaps to Be Researched

- Expanded list of inorganic, metals and organic (VOCs, SOCs, and pesticides)
- Cyanide
- What does adding low concentrations of lots of different contaminants mean to health/environment?
- Do salt impurities vary with the source of salt?
- Is it possible to avoid infiltration of stormwater originating from winter months?
- Monitoring
  - Occur on a regular frequency
  - Utilize analytical methods with low reporting limits
  - Specifically target recharge events
  - More intense when chemicals (sealcoats, salt or pesticides) are applied